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Usefulness of magnetic motor evoked potentials in the surgical treatment of hemiplegic patients with intractable epilepsy

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Five hemiplegic patients with intractable epilepsy were studied with transcranial magnetic stimulation (TMS) before and after various surgical treatments. These patients had unilateral widespread cerebral lesions acquired at various times, including congenital, infantile and childhood injury. Motor evoked potentials (MEPs) of the abductor pollicis brevis (APB) muscles were simultaneously recorded on both sides following TMS of the motor cortex in the respective hemisphere using a figure-8 or circular coil. In all patients with congenital disease, the abolition of motor function in the affected hemisphere was estimated by magnetic MEPs, and the hemiplegia did not deteriorate after functional hemispherectomy (HS) was performed in two of them. In two patients with acquired disease, HS was not performed because it was shown by magnetic maps that the motor function in the affected hemisphere remained. Furthermore, it was shown by electric MEPs using subdural electrodes that a patient who had had encephalitis in early childhood had a reorganised motor area in the parietal cortex of the affected hemisphere. The present findings indicate that magnetic MEPs are a very useful non-invasive method of assessing whether the motor area in the affected hemisphere can be resected in hemiplegic patients with intractable epilepsy.

Key words: magnetic MEPs; hemiplegic patient; epilepsy surgery; reorganisation; motor function.

INTRODUCTION

Hemispherectomy (HS) has been widely accepted and employed for surgical treatment of intractable epilepsy since Krynauw reported that the procedure not only controlled seizures but improved the patient's behaviour[1]. A good indication for HS is when patients have severe hemiplegia due to widespread hemispherel epileptogenic abnormalities and are expected to show no deterioration in neurological deficits after surgery. However, in patients with early brain lesions, especially congenital or infantile, HS has sometimes been performed even if the hemiparesis was mild, because it has been shown in practice that functional recovery is much better than in patients with late brain lesions, such as brain tumours or strokes[2–6]. In such patients, it is very important (but also very difficult) to quantitatively estimate motor function before surgery to predict post-operative function.

In this study, we examine the relationship between magnetic motor evoked potential (MEPs) and motor function during assessment for hemiplegic patients with a possible indication for HS, and discuss the usefulness of magnetic MEPs in the prognosis of motor function.

METHODS

We studied five hemiplegic patients with intractable epilepsy who generally had unilateral widespread cerebral lesions from various cerebral injuries, including congenital, infantile and childhood acquired lesions (three males and two females, 1–17 years

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Table 1: Clinical features and MRI findings.

Number	Age (year)/sex	Aetiology	Injury period	MRI localisation	Motor function (hemiparesis)
1	1.9/F	Lissencephaly	Congenital	R, C	L, moderate
2	1/F	SW syndrome	Congenital	R, C	L, moderate
3	12/M	Schizencephaly, polymicrogyria	Congenital	Blt (R>) C, S	L, moderate
4	16/M	Encephalitis	4 years	R, C	L, slight
5	17/M	Encephalitis	2 months	R, C	L, slight

M, male; F, female; SW, Sturge–Weber; Blt, bilateral; R, right; C, cortical; S, subcortical; L, left.

old at the time of the study) (Table 1). Three patients had congenital lesions; lissencephaly in one, Sturge–Weber (SW) syndrome in one, and schizencephaly and polymicrogyria in one. Two patients had encephalitis at 2 months and 4 years of age, respectively. The sites of the lesions were identified by magnetic resonance images (MRIs). Only one patient with schizencephaly and polymicrogyria had bilateral cortical and subcortical lesions in the right dominal hemisphere, while the others had cortical lesions in the left hemisphere. Hemiplegia in all patients was characterised by good residual motor function in proximal, rather than distal, muscles and the degree of paresis was moderate in the congenital patients and mild in the others.

Transcranial magnetic stimulation (TMS) was delivered by a magnetic stimulator, Magstim model 200 (Magstim Co. Ltd., Whitland, UK) through a figure-8 coil or a circular coil with a maximal output of 2.2 T. Each loop of the former coil had a 70 mm outer diameter. The intersection of the loops was tangentially positioned over the scalp surface, beneath which the hand motor cortex was expected to be in each hemisphere. The circular coil, which had a 90 mm outer diameter, was used only in one patient with lissencephaly, because we had difficulty in inducing estimable MEPs from her with a figure-8 coil. The centre of the coil was tangentially positioned over Cz and was turned over to stimulate each hemisphere favourably. The patients lay on a bed at rest and MEPs were simultaneously recorded from the bilateral abductor pollicis brevis (APB) muscles using surface electrodes positioned over the belly muscle 3 cm apart. The stimulus intensity was threshold plus 20%. When MEPs of APB muscles in the paretic side could not be induced, the stimulus intensity was increased to the maximum. Filters were set from 100 Hz to 5 kHz, and the analysis time was 50 milliseconds. The peak-to-peak amplitudes of four MEPs were measured and the differences of the averaged values were compared before and after surgery. Two patients (case 3 and 4; Table 1) had subdural electrodes placed over the cortical surface in the uni- or bilateral hemisphere via a craniotomy because the seizure focus was identified. Additionally, mapping of the hand motor cortex was performed by bipolar electric stimulation using electrodes laid side by side at 1 cm intervals. The stimulus intensity was threshold plus 20%. MEPs were simultaneously recorded from bilateral APB muscles five times, and summed.

We obtained informed consent from all patients or the parents of the children before the study. The patients tolerated TMS without any adverse effects. TMS did not provoke seizures during or after the procedure in any patient.

RESULTS

One patient with lissencephaly in the right hemisphere (case 1, Fig. 1A) had no MEPs from the paretic APB muscles by TMS of the bilateral hemisphere using a circular coil before surgery (Table 2, Fig. 1B). She had a functional HS of the affected hemisphere, which was identified as the seizure focus (Fig. 1C). After surgery, the paretic distal muscles slightly recovered and MEPs of bilateral APB muscles were obtained by the same stimulation as before surgery. Moreover, the MEPs of non-paretic APB muscles had increased amplitudes (Table 2, Fig. 1D).

In one patient with the SW syndrome in the right hemisphere (case 2), no MEPs of bilateral APB muscles could be elicited by TMS of the affected hemisphere using a figure-8 coil before surgery (Table 2). She had functional HS of the affected hemisphere, which was identified as the seizure focus. After surgery, it was impossible to obtain MEPs from her because she refused to be examined. Her paretic limb did not get worse.

In another patient with congenital lesions, schizencephaly and polymicrogyria (case 3, Fig. 2A), MEPs of the bilateral APB muscles could not be elicited by TMS of the affected hemisphere, but could be obtained simultaneously by TMS of the unaffected hemisphere before surgery (Table 2, Fig. 2B). Subdural electrodes were placed over the cortical surface in the bilateral hemispheres (Fig. 3A) because the seizure focus could be not identified by scalp EEG. MEP mapping with subdural electrodes showed almost the same results as TMS. Moreover, the distance between the sites of

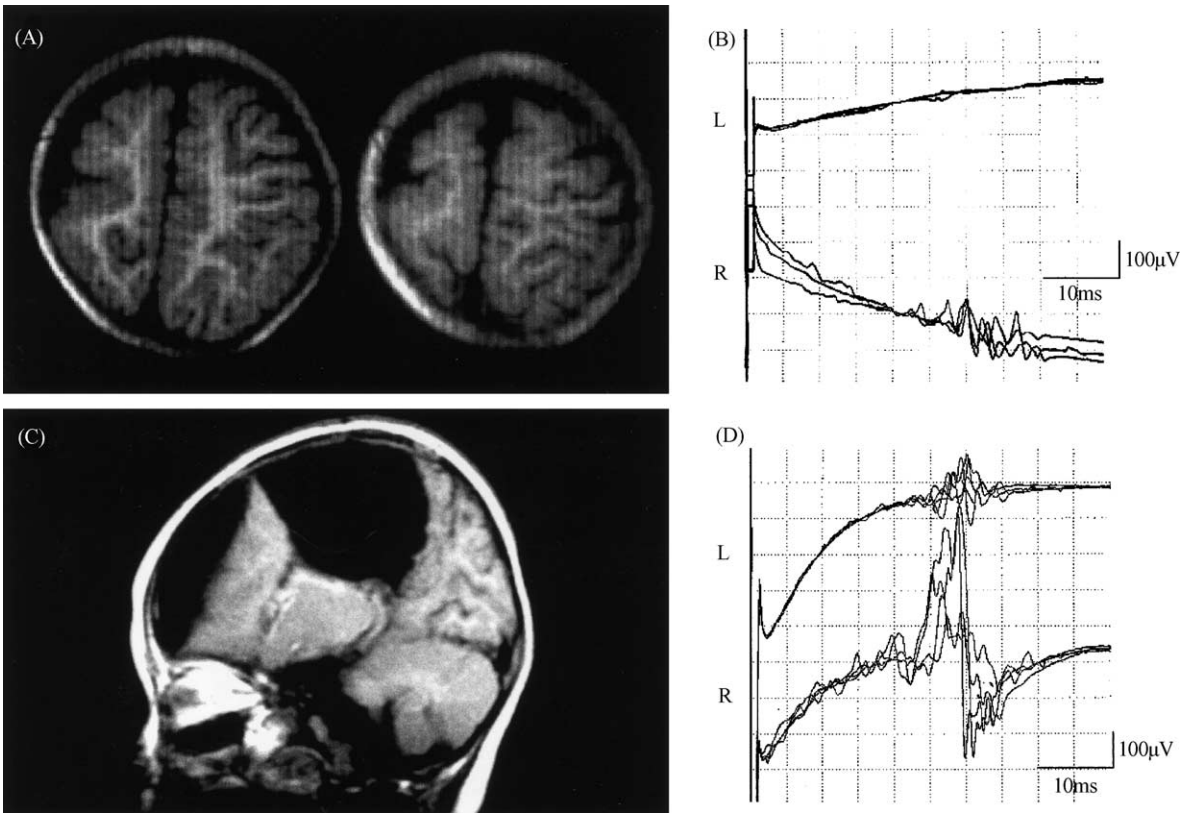

Fig. 1: (*A–D*) T_1-weighted magnetic resonance images showing lissencephaly in the right hemisphere (*A*; case 1). MEPs from bilateral recording of APB muscles following TMS using a circular coil before surgery (*B*). Sagittal magnetic resonance image showing functional hemispherectomy (*C*). MEPs from bilateral recordings of APB muscles after surgery (*D*).

the highest ipsilateral MEPs (Fig. 3B; a-4) and that of the highest contralateral ones (Fig. 3B; a-3) was about 1 cm, and the latencies of the MEPs were close (Fig. 3). This patient underwent lesionectomy of the right parietal lobe, which was identified as the seizure focus (Fig. 2C). After surgery, the paretic distal muscle slightly recovered and the MEP amplitudes of the bilateral APB muscles by TMS increased (Table 2, Fig. 2D).

One patient with an encephalitis history had widespread atrophy in the right hemisphere (case 4) on MRIs. Fluid attenuated inversion recovery (FLAIR) MRI showed a high intensity lesion (Fig. 4A). Contralateral responses were elicited by TMS of each hemisphere using a figure-8 coil before surgery (Table 2, Fig. 4B). In this patient, no response of the bilateral APB muscles could be obtained by direct bipolar electric stimulation of the affected motor cortex, but responses similar to those elicited by TMS were obtained by electric stimulation of the affected parietal lobe. The site was identified as the sensory cortex by sensory evoked potentials (SEPs). He

Table 2: Operations and results of transcranial magnetic stimulation.

Number	Operation	MEP							
		Pre-operative				Post-operative			
		L-stim		R-stim		L-stim		R-stim	
1	R, HS	L−*		R+*		L+#*		R+#*	
2	R, HS	L−	R+	L−	R−	Incomplete			
3	R, parietal lesionectomy	L+	R+	L−	R−	L+#	R+#	L−	R−
4	R, frontal lesionectomy	L−	R+	L+	R−	L−	R+#	L+#	R−
5	Anterior CC	L−	R+	L+	R−	L−	R+#	L+#	R−

MEP, motor evoked potential; L-stim, stimulation of left motor cortex; R-stim, stimulation of right motor cortex; R, right; L, left; +, appearance of MEP; −, no response of MEP; #, increased amplitude of MEP; HS, functional hemispherectomy; *, using circular coil; Incomplete, incomplete study; CC, corpus callosotomy.

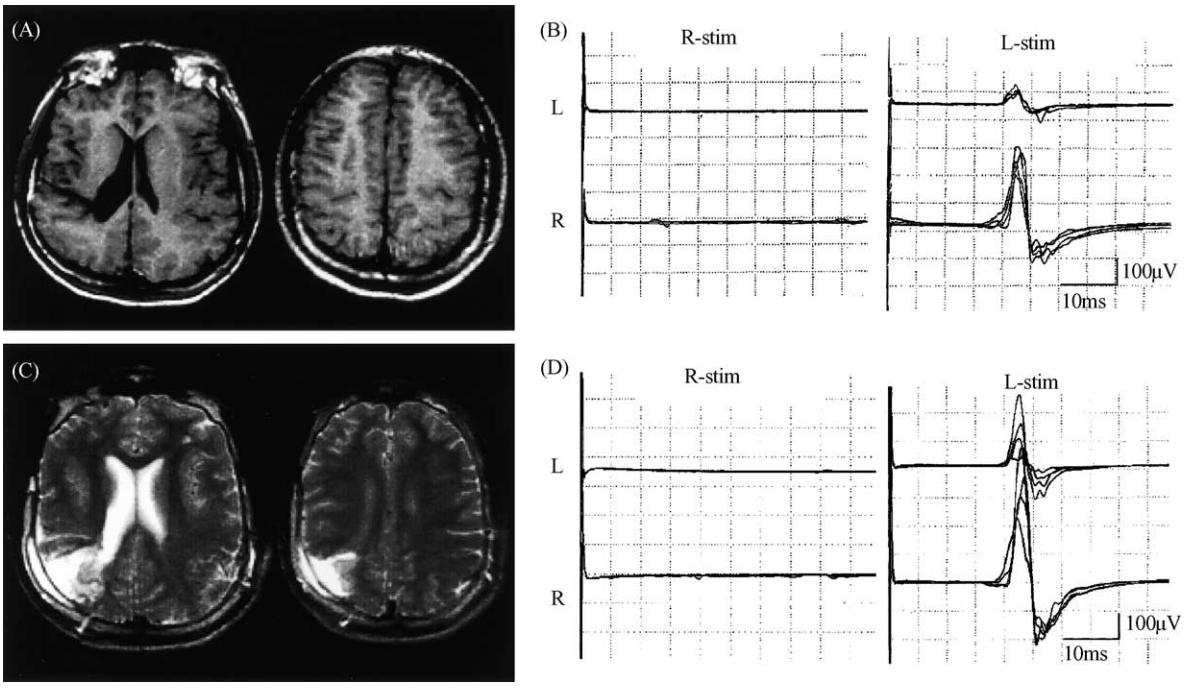

Fig. 2: (*A–D*) T_1-weighted magnetic resonance images showing schizencephaly and polymicrogyria in the bilateral (right dominated) hemisphere (*A*; case 3). MEPs from bilateral recording of APB muscles following TMS of the right (*B*; left) and left (*B*; right) motor cortex before surgery. T_2-weighted magnetic resonance images showing lesionectomy of the parietal lobe identified as the seizure focus (*C*). MEPs from bilateral recordings of APB muscles after surgery (*D*).

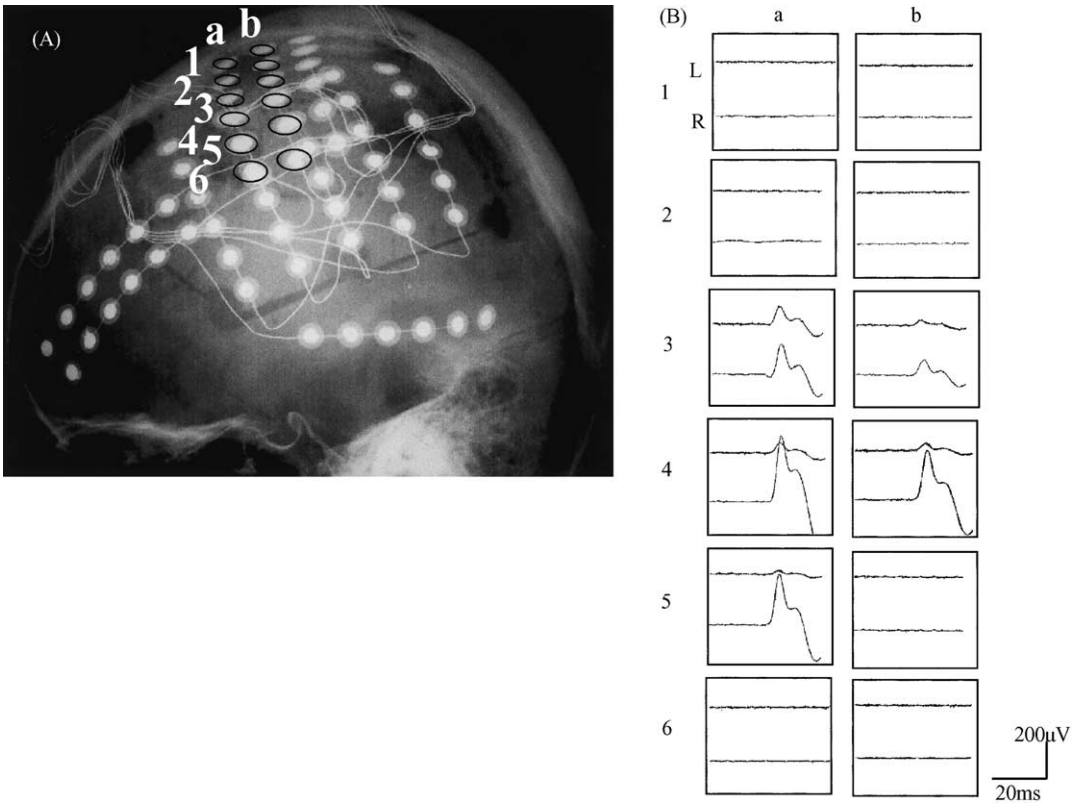

Fig. 3: (*A* and *B*) Skull radiographs in lateral projections showing subdural electrode coverage of the motor cortex surface in the unaffected hemisphere (*A*; case 3). MEP bilateral recording of APB muscles following bipolar electric stimulation using electrodes laid side by side at 1 cm intervals.

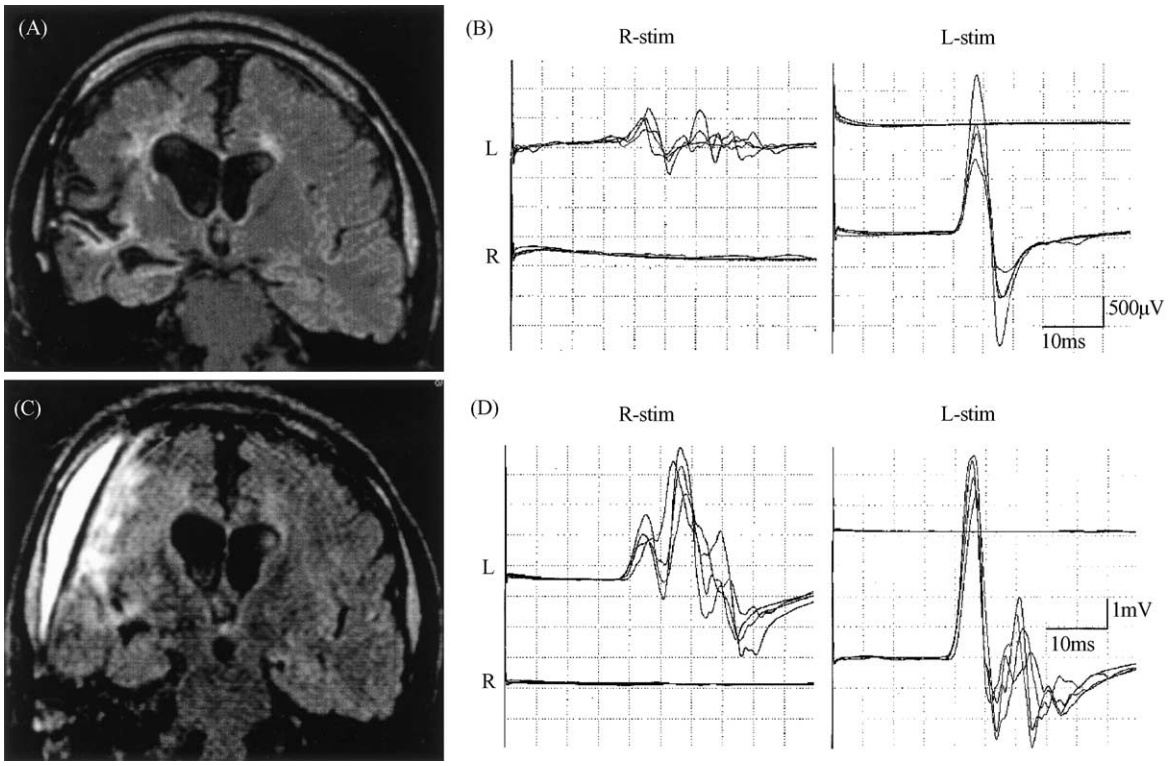

Fig. 4: (*A–D*) FLAIR magnetic resonance image showing widespread atrophy and a high intensity lesion in the right hemisphere (*A*; case 4). MEPs from bilateral recordings of APB muscles following TMS of the right (*B*; left) and left (*B*; right) motor cortex before surgery. FLAIR magnetic resonance image showing lesionectomy of the motor cortex and subdural hematoma as post-operative changes (*C*). MEPs from bilateral recordings of APB muscles after surgery (*D*).

underwent lesionectomy of the motor cortex, which was identified as the seizure focus. His paretic limb improved slightly and the amplitudes of MEPs elicited by TMS using a figure-8 coil increased after surgery in both hemispheres (Table 2, Fig. 4C and D).

Another patient with encephalitis (case 5) showed the same results as shown in case 4 on MEPs before and after surgery (Table 2). He underwent anterior corpus callosotomy in place of HS.

DISCUSSION

HS has been the usual surgical treatment for hemiplegic patients with intractable epilepsy. However, there has been no previous report of the motor area of an affected hemisphere being resected safely after demonstrating its abolishment by an objective method before surgery. In this study, all three patients with congenital lesions had no MEPs of APB muscles by TMS of the affected hemisphere before surgery. We confirmed the abolishment of their motor function from these results and could perform HS safely without making hemiplegia worse in two of them.

Another patient had lesionectomy of the parietal lobe in the affected hemisphere. The hemiplegia of this patient would probably might not deteriorate after surgery even if HS was performed.

Some authors have reported that ipsilateral MEPs of distal muscles by TMS of the unaffected hemisphere were observed frequently in patients with early brain lesions, while no motor response was seen from the affected hemisphere[7–13]. It has been postulated that ipsilateral MEPs originate from the branched corticospinal tract fibres of the unaffected hemisphere because of the similarity of amplitude map distributions and the approximation in latency between the ipsilateral and contralateral MEPs. We thought that it might be impossible to elicit MEPs successfully in patients with congenital lesions because of their abnormal motor pathway structures, and tried to record electrical MEPs, which had been not reported in previous studies. As a result, our study of electrical MEPs found the same results as previous studies using magnetic MEPs, and confirmed the above speculation.

On the other hand, in our study, two patients with hemiplegia due to encephalitis had MEPs of APB muscles by TMS of the affected hemisphere before surgery. The magnetic MEPs were proved to originate from the reorganised motor area in the ipsilateral parietal cortex in one of them. It was also thought in another patient that the motor function of the affected

hemisphere might still remain. In hemiplegic patients who have had magnetic MEPs of the affected hemisphere, surgeons should avoid taking the easy option of HS and first investigate the relationship between the seizure focus and motor area in the affected hemisphere sufficiently using subdural electrodes.

There have been no previous reports estimating the motor function objectively and quantitatively before and after epilepsy surgery. In our study, functional HS resulted in slight improvement of motor function in two patients with negative MEPs in the affected hemisphere. One of these had increased MEPs after surgery. In addition, all the other patients also showed increased MEPs and improvement of motor function after various surgical treatments. These results may be explained by this hypothesis: seizure-freedom or a marked decrease in seizures after surgery may have some positive effect on the ipsilateral or contralateral motor function, although the detailed mechanism is unknown.

In conclusion, in hemiplegic patients with intractable epilepsy, magnetic MEPs are a very useful non-invasive method of assessment to determine if the motor area in the affected hemisphere can be resected, and for seeing functional prognosis after surgical treatment. However, our findings are based on a very small population. In future studies, the relationship between magnetic MEPs and motor function during assessment for surgery should be examined in hemiplegic patients with unilateral widespread cerebral lesions from various causes and time of critical insult, and compared with electric MEPs using subdural electrodes, if possible.

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